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Bailey Balfour address
to the medical students
at the opening of the
winter session, University
of Glasgow 28. Octr
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Some Resemblances betwixt Plants and Animals in respect of their Nutrition,
with
Some Remarks on the position of the Natural History Sciences in Medical Education.

ADDRESS

TO THE

MEDICAL STUDENTS

AT THE

OPENING OF THE WINTER SESSION,
UNIVERSITY OF GLASGOW,
TUESDAY, OCTOBER 28th, 1879.

BY

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GLASGOW:
1879.

ADDRESS.

GENTLEMEN,

It is my duty to address to you to-day, on behalf of my colleagues, some words of welcome at the commencement of this session—a session, to some of you, the entrance upon a course of study of a loftier and more noble character than any on which you have hitherto been engaged; to others, a revival of scenes already familiar, and marking another stage of progress towards the goal of your ambition; to all, a period in that time of intellectual activity, intervening betwixt the relaxation of school discipline and your outset on life which, whether used or misused, must have an important influence on your future.

The obvious intention of the custom of an address at the advent of a new session to furnish an opportunity for offering encouragement and counsel and advice to those engaged on so important a branch of professional study, has been embraced by many of those who have preceded me. But I have felt that any words of that nature I might utter, would, wanting that quality by which age and experience makes them impressive, be inappropriate, and, if they did not weary you, might fail to enlist your sympathy. I have therefore preferred to seek the materials out of which to spin the thread and weave the web of my discourse in those regions of science with which I am most familiar; and, in further explanation, it is right to state that I appear before you to-day out of due time. The duty I now perform ought in proper course to have fallen to the lot of my colleague in the Chair of Anatomy

but, as in the somewhat exceptional circumstances of the establishment of my connection with this University, it was considered inadvisable that I should deliver at the time an inaugural address, the present occasion seemed a fitting opportunity for the discharge of that duty.

Since the time, some twenty years ago, when the identity, so far as cognisable by any means at our disposal, of the sarcode of the animal body with the protoplasm of the plant organism was demonstrated, all biological research has proceeded in the direction of showing how similar are the vital phænomena exhibited in the two kingdoms of organic nature, what a fundamental unity of principle there is amidst the vast and complex variety of detail, that the faculties of all living matter, however diverse in degree, are yet substantially alike in kind; and, indeed, it would be strange were it otherwise, when the physical basis of all life is this one substance—protoplasm.

My purpose to-day is to direct your attention to some points of similarity in the function of nutrition as exhibited by plants and by animals, and to point out to you how essentially alike are the processes of *digestion* and of *respiration* in the members of the two kingdoms. I have the more readily selected this as subject-matter of my remarks, for whilst the outline of these phænomena in the animal is, probably from considerations of self-interest, pretty well known, a strange and unfortunate misconception is prevalent, not among the general public merely, but also amongst many of those whose avocations are more specially scientific, as to the exact nature of these processes in the plant body—a misconception witnessed to by misleading forms of expression and by statements in works on physiology of no mean repute, and of recent date, as to the antagonism between plants and animals, especially in the latter respect, and to which may also, I believe, in some measure be traced many of the pernicious ideas (unfortunately too common) regarding the value of a knowledge of plant life to those whose energies are eventually to be devoted to the

practice of an art which concerns life in its highest manifestation.

It is expedient that in the first place I briefly indicate some of the salient features in the process of nutrition in animals with which I desire to institute a comparison; for, as the time at my disposal is limited, I cannot hope to give more than an outline sketch.

The proximate principles of the food of animals are, as you are aware, of two kinds, inorganic and organic. To the former class belong water and the various mineral salts, whilst the latter may be divided into the three groups of the amyloid carbo-hydrates, as starch and sugar; the fatty carbo-hydrates; and the albuminates or nitrogenous principles. You all know the important generalisation that animals must receive their organic food principles ready formed; they are unable to manufacture them for themselves. This not, however, absolute, for it has been long known that, in certain simple forms among the Infusoria, rests the power of constructing organic compounds (carbo-hydrates) out of inorganic elements; and recently Geddes has shown that in many land-planarians a like power resides. These exceptions, few in number though they be, are yet deserving of attention as proving the occasional occurrence in the animal kingdom of a power markedly resident, as I shall presently point out in detail, in certain plants.

Now these proximate principles combined in food as taken into the animal body are not in a form to be directly applied to the repair of the waste tissue and to the maintenance of the organic activities of the body. The water and mineral salts (after solution) may be at once absorbed, but the organic principles must be subjected to the influence of a series of conditions by which their chemical constitution is altered, their physical character is changed, and they are rendered fit to serve their part in the nutrition of the animal—they are *digested*.

The most important factors in this process of transformation are the various animal juices with which the food

comes in contact. The number and character of these vary with the position of the animal in the scale of complexity; and they act in virtue of certain matters dissolved in their substance which are capable of exciting chemical changes in the food elements. These contained bodies, the composition of which no analytical method has as yet determined, and consequently their actual mode of working is unknown, are classed as ferments, and the process of digestion which they incite is essentially one of fermentation. The ferments known in the animal body are numerous, but in correspondence with the three classes of organic food principles we may consider those that are immediately concerned with their digestion as falling into the three classes of (*a*) the amylolytic, (*b*) the emulsive, and (*c*) the albuminosic, the ferments of any one class being capable of acting upon but one kind of food principle, although ferments of more than one class may be present in any one animal fluid.

Of the amylolytic ferments—those which act upon the starch and sugar of the food—there is in the saliva, *ptyalin*, which effects the transformation of starch into grape sugar, whilst in the intestinal juice a ferment which causes the inversion of cane sugar is found.

In the pancreatic juice a ferment of the second class exists, the special province of which is to emulsionise the fatty principles of the food.

Lastly, the albuminous principles are converted into soluble peptones by means of the *pepsin* of the gastric juice.

The illustrations I have selected of these ferments are prominent examples—one from each class as they occur in the higher groups of mammals, for there they have been most studied and are best known. But investigation is daily making it clear that in all animals there are similar ferments, differing in amount and intensity of power in accordance with specific habits and faculties. It must, however, be borne in mind that ferments of other kinds occur in the animal body which possibly play a more or less important part in nutrition, but of them our knowledge is at present imperfect, and more-

over, it is not necessary for my present purpose to take note of them.

As an outcome of this process of digestion, the food principles are brought into a form suitable for absorption. The nutrient portion of the food is then strained off into the blood as the internal medium by which transit is accomplished, and the recuperative particles are carried to the various parts of the body. The nutrient molecules at the seat of final distribution transfuse the walls of the delicate capillaries into the surrounding tissues, and at the same time the effete matter which functional activity entails is transfused as waste product into the blood, and removed in its current, to be finally eliminated and excreted from the organism along with the residue of non-nutrient material taken into the body with the food elements. The blood thus has the twofold function of acting as a current of supply of pabulum to the tissue, and as a system of drainage for effete matter. What kind of food particle is requisite for any tissue concerned in any one particular form of energy, and how the food particles are ultimately homologated with tissue substance, is still hypothetical.

Now, in the combustion, which work done by the tissues involves, and in the development of heat necessary for life, there is always an evolution of carbonic acid. The accumulation of this gas is prejudicial, nay, fatal, to the economy, and its removal is therefore imperative. This, too, is effected by the blood, which also brings to the tissues the quantity of oxygen requisite for the transference of energy and the continuance of activity. The blood thus acts as a carrier of carbonic acid from, and a bearer of oxygen to, the tissues; the capability of the blood for the latter function depending upon the affinity for oxygen possessed by the hæmoglobin attached to its red corpuscles.

This interchange of gases constitutes the phænomenon of *respiration*—an oxidation process—required for the performance of function and the production of animal heat, and therefore for the life and growth of the organism; and the

animal is unable to sustain life for any lengthened period in absence of, or with insufficient supply of oxygen. The balance between supply and demand for oxygen is kept up in the lungs, or in whatever organ may take their place, and there it is that the interchange betwixt the gases of the blood and those of the medium in which the animal lives is accomplished, a process commonly spoken of as *respiration*, but which is more properly termed, *external respiration*, as distinguished from those deep-seated changes between the blood gases and the tissues, which is the true or *internal respiration.*

In those simpler animal organisms, where no closed vascular system exists, the general terms of the problem are the same. Digestion is, however, followed by direct absorption of nutrient matter over an extended area of the body, and the interchange of gases is associated with no particular organ, though the presence of oxygen is as necessary, and the concurrent evolution of carbonic acid as evident, as in more complex forms.

Such is a rapid sketch of some of the important features in the processes of digestion and of respiration in the animal organism; and you will note that digestion is essentially a fermentation effected by ferments severally fitted for the different principles of the food, and that coincident with this, respiration supplies the oxygen necessary for combustion, and the evolved carbonic acid is removed. With this as a basis of comparison, let me now endeavour to make clear these processes in the vegetable kingdom.

Here it is of primary importance to distinguish two large classes of (*a*) *green* plants; (*b*) those that are *not green.* To the non-recognition of this fundamental difference is to be traced much of the confusion which has for so long characterised commonly-accepted notions on this subject. To a casual observer the necessity for the distinction may not at first sight appear; for are not green plants the most complex and numerous of plant organisms? Is it not from them that we derive our ordinary conception of a plant?

This, to a certain extent, is true. Those green plants are undoubtedly the most highly organised; in point of number, however, they are probably far surpassed by those forms which are not green, and of which the various kinds of so-called fungus are best known. But as with the presence of the green colour is associated a power of obtaining materials for nutriment, and probably also a means for the regulation of the respiratory process denied those forms which are not green, and the groups are therefore separated by a physiological, as well as by a morphological character, an examination of each severally is demanded.

First, then, with regard to the green plants, their colour is due to a substance of complex composition—chlorophyll—attached to the protoplasm of the cell, which may or may not be differentiated to small rounded portions, the chlorophyll bodies. From the protoplasm the chlorophyll can be easily separated in solution. It is formed under the influence of light; a normally green plant when grown in darkness, as is familiar to all of you in leaves of celery, or in young shoots of asparagus, being etiolated or blanched. In some few cases (leaves of ferns and seed-lobes of conifers) when temperature and other conditions are favourable, chlorophyll appears to be formed in darkness.

These green plants are able, under suitable conditions, to take, and do take in all the substances requisite for their nutrition as inorganic compounds—water, carbonic acid, ammonia and mineral salts being the chief of these. That a small amount of nutrient matter is absorbed as ready formed organic compounds is no doubt also true, but the quantity so supplied is comparatively small. From inorganic elements the plant is able to manufacture the proximate organic compounds—the amyloid, the fatty and the nitrogenous—for its nutrition, and the mode in which these inorganic elements are obtained must now be noticed.

In presence of light, a constant absorption of carbonic acid is going on in the green parts, chiefly in the leaves the carbonic acid is decomposed, oxygen is given off, and

the carbon entering into combination with other elements, a carbo-hydrate is formed within the chlorophyll cells. It is in this manner, by this process of so-called *assimilation,* that green plants acquire the amyloid and fatty principles for their nutrition. I say so-called assimilation, for this term, to which in animal physiology and in general literature quite another signification is attached, has been applied by German authors to this deoxidation process—an unfortunate misuse of a word, as thereby it is not a little confusing to read that whilst green plants are able to assimilate their food elements, plants which are not green do not assimilate. The term has, however, been so generally used in botanical literature, that it is impossible now to rectify the misapplication. Hitherto the chlorophyll has been regarded as the agent by which, in presence of light, this decomposition is effected, and many chemical theories in explanation of the process have been advanced, that most commonly received referring the power to iron salts in the chlorophyll. But Pringsheim's recent investigations, by his new method of microscopical photo-chemistry, have resulted in the interesting and important discovery, still, however, requiring confirmation, that chlorophyll has no direct influence in this assimilation, and the deoxidising power must reside within the protoplasm itself, incorporated, it may be, in some as yet unrecognised constituent. What the first product of this decomposition and recomposition is—whether starch, or sugar, or fat — has evoked much discussion. Certain is it that in dicotyledonous plants the chlorophyll bodies are usually rich in starch granules; whilst on the other hand, in the leaves of monocotyledonous plants starch granules are not of common occurrence, though grape sugar can always be detected; and again in most plants small oil globules are found in chlorophyll cells. But on this point, too, Pringsheim's researches throw some light, for he has demonstrated an oleaginous matter, which he terms *Hypochlorin,* within the protoplasm of the chlorophyll bodies, easily extracted from them, and this substance, very sensitive

to light, is, he considers, the primary assimilation-product from which the carbo-hydrates are subsequently formed.

The nitrogen of the atmosphere is not directly absorbed by the plant for the manufacture of albuminates; it is probable, however, that a certain amount of the required nitrogen is obtained by epigeal parts in the form of carbonate of ammonia. The main source of their nitrogen is the ammonia compounds and nitrates in the soil, which, along with water and the mineral salts, are absorbed by the delicate root-fibrils. These exercise a selective power, excreting an acid substance to bring solid matter into a condition in which it can diffuse through the cell walls; and substances thus obtained from the soil pass up through the tissues as the crude sap. In this way the elements for the formation of nitrogenous proximate principles—such as gluten and legumin—are derived, the construction of these from the inorganic elements proceeding in cells without chlorophyll as well as within chlorophyll cells, no part of the cell being specially concerned, and light is non-essential.

In these ways, then, the proximate organic compounds required for nutrition, which are of the same character as those wanted by the animal, are by green plants manufactured from inorganic elements, though, at the same time, they do take in a certain amount of ready formed organic matter. The terms of the generalisation thus formulated are therefore the inverse of that enunciated for the animal kingdom.

The faculties of non-green plants, on the other hand, are more limited, and, we find, a nearer approach to the animal world. The funguses are, as I have said, the most numerous members of the group; but into the same category come a number of parasitic plants such as scalewort, broom-rape, and those plants known as saprophytes, which make of decaying vegetable matter a nidus—for example, the bird-nest orchid. Of these we may say that like animals they take in their organic principles ready formed; they obtain no carbon directly from the atmosphere; with the chlorophyll they have lost the power of assimilation. Carbo-hydrates, as such, are by them

absorbed, their character varying with the nidus, and in this connection it may be noticed that starch is never found within the tissues of funguses. Nitrogenous compounds are also directly taken up, though the power of manufacturing these out of inorganic elements is still in many non-green plants retained. How different, then, they are from green plants, and how inadequately expressive of the facts of the case is the oft recurring statement, "Plants are the manufacturers, animals are the consumers, in the world's economy."

The proximate principles, then, for nutrition,—starch and sugar, the fats, the albuminous bodies,—as they are formed within the plant body, are not in a condition proper for nutrition. They must be digested, and this is accomplished by a process termed *metastasis,* the true digestion of plants.

It has been for long known that during the germination under favourable conditions of heat and moisture of the seeds of cereals, there is a gradual breaking down of the stored starch granules, concurrently with a development of grape sugar in the tissues. This phænomenon, familiar in the malting of barley, was first shown by Payen and Persoz, to have as its cause a peculiar nitrogenous substance which they separated from the grain, and named *diastase,* believing it to be a pure chemical ferment. By this fermentation the food elements of the grain are prepared to be utilised by the growing embryo-plant, and it is a digestive process.

The capability of isolation of the *diastase* and its power in this state of inciting fermentative changes, indicates that this digestion is subject to purely chemical laws, and were a confirmation wanted, we find it in the interesting experiments by Claude Bernard as to the effects of anæsthetics upon plants. For he has demonstrated that in anæsthetised germinating seeds, whilst the protoplasm is rendered inactive, and the vital phænomena manifested in growth and development cease, the purely chemical process of the transformation of starch into grape sugar incited by the *diastase* continues uninterruptedly.

One of the most weighty discoveries in modern plant phy-

siology was made by Sachs, when he observed that the starch granules formed by assimilation in daylight within the chlorophyll bodies in leaves disappeared during the succeeding period of darkness. From what is now known, there is no doubt that during daylight also there proceeds a constant solution of the starch granules, but the reconstructive process of assimilation overmatches the destructive, and there results an accumulation of starch at the close of day within the chlorophyll bodies. That the factors in this change are the same as those found in germinating seeds was reasonably to be inferred, but the proof has only recently been furnished by Baranetzky who has demonstrated the presence of a starch-transforming ferment in the cells, not only of the leaves, but of the stems of many plants; and we may now safely conclude that it is present in all cells, whether containing chlorophyll, or free of it, in which starch is found, and by its action the starch is metamorphosed, and takes a soluble and diffusible form.

In such plants as the sugar-cane and the beet-root, the products of assimilation take ultimately the form of cane sugar. This substance to be of use must be inverted, and this is accomplished by the agency of a ferment identical with that found in the animal body. Claude Bernard, who first propounded the existence of the inversive ferment in beet-root has, by his experiments with anæsthetics, furnished a most interesting proof of its existence in the yeast plant, which is still capable, when anæsthetised, of inverting cane sugar; the unorganised inversive ferment, destitute of sensibility, continuing to perform its work. In the plant body, the digestion of amyloid carbo-hydrates (starch and sugar) is thus performed in a manner analogous to that in the animal kingdom.

Hitherto no emulsionising ferment has been identified in, or isolated from, vegetable tissue. That such exists there is abundant indication, for not only are oil globules observed in the assimilating cells, but in numerous seeds, such as those of poppy, flax, castor-oil, and others, the reserve materials take

mainly the form of fats and oils, and in that condition are incapable of rendering service to the embryo. That the oil in such seeds is, indeed, destined as food to the embryo has been plainly determined by Gressner, who watched under the microscope in the seeds of Cyclamen the gradual disappearance of the oil globules for absorption by the embryo, the process commencing in the cells of the cotyledons nearest the growing parts. Moreover, the emulsionising power of some substance in the seed is shown by the fact that oily seeds, when bruised in a little water, readily form an emulsion. Further investigation will, doubtless, result in the isolation of the ferment, whose presence is thus evidenced.

The occurrence of peptic ferments in plants, which effect the metastasis of albuminous bodies, has in recent years attracted considerable attention. You are all no doubt cognisant of the existence of the so-called carnivorous plants, and of the facts regarding them which the elaborate investigations of Darwin have made known. Taking for example the sundew, there is excreted from the glandular hairs of the leaf surface a pepsin ferment, which, acting upon the albuminous constituents of the bodies of insects entangled by the viscid matter coincidently secreted from the glands, gradually digests them, and converts them into peptones, a form in which they may be absorbed and applied to the purposes of plant life. Here, then, is a marvellous analogy with the animal. And yet there have not been wanting those who refuse to recognise the importance of these changes to the plant, who regard the occurrence of a substance with such power excreted by the plant, as too anomalous to be accredited, and, even when chemical analysis has placed this point beyond the pale of discussion, would still, notwithstanding the extended observations of Francis Darwin, Reess, and others, deny the possibility of its proving of any service to the plant. Is there any one who would deny the existence of a ferment in the saliva, an external secretion, and its power of transforming starch into sugar, and will any one say that the sugar is of no use in the animal economy?

Assuredly not. Is it, then, any more extraordinary to find a pepsin ferment in an external secretion from the plant body?

But our knowledge of the presence of pepsin ferments in the vegetable does not rest merely on these carnivorous plants. Albuminates are abundant in vegetable tissues, and in many seeds, especially in Leguminosæ, form a great part of the reserve material, which must be digested for the embryo. Gorup-Besanez has succeeded in extracting from a species of vetch the ferment which promotes this end, and which, when isolated, acts very powerfully on animal albuminates. Wittmack has also obtained in large quantity from the papaw tree a pepsin ferment which digests albuminates, and this substance is of some importance, and as it seems to me worthy the attention of the medical profession, for, when isolated, it acts not so much on the fibrine of the animal body, but, as Lauder Brunton informs me, upon the connective tissue, thus affording an interesting scientific explanation of an Eastern popular belief that this tree has the property of rendering fresh meat tender.

I have said enough to make it plain to you that the albuminous principles of the food of plants are digested precisely as they are in animals, but I will bring before you two other illustrations, which are of considerable interest, as affecting certain collateral questions.

There is a group of simple organisms now known as Myxomycetes, which at one period of their life history present the appearance of masses of free protoplasm. These masses constantly move over the surface of their nidus by shooting out lobes of protoplasm, and again retracting them, only to protrude them in like manner from another spot. In this state they exhibit those features so well known as characterising some of the simplest forms of animals, such as are typified in the Amœba. We might, in fact, consider this mass, this plasmodium as it is termed, of the myxomycete, a land-bathybius, had not our marine friend belied his early promise, and descended to the realms of the inorganic. These masses of variously coloured protoplasm, which may be known

to many of you as constituting on the surface of the tanpits the flowers of tan, possess a remarkable power, as De Bary first pointed out, of ingesting solid particles from which nutriment is extracted, and these, after a longer or shorter sojourn within the substance of the protoplasm, are extruded, by the gradual flowing away from them of the mass. This remarkable power which for so long had been considered an absolute diagnostic mark of animals, led many to regard these organisms as belonging to that kingdom. But their plant nature being clearly proved, their nearest allies belonging to the group of Fungi, the discovery of their life history effectually disposed of what had long remained the only distinction between the two kingdoms. The question, whether the ingested matter was really made use of by the organism, or was merely accidentally included by the protoplasm in its passage over it next naturally suggested itself. This point has been recently set at rest by Kühne, who has proved the existence of a pepsin ferment within the plasmodium, a ferment which, on separation, digests albuminous bodies more powerfully than many ferments found in invertebrated animals. An important link in the biological chain has thus been completed.

The second illustration to which I would refer is an outcome of the prolonged investigation by Nägeli into the process of fermentation, whereby he has shown that in the cells of yeast a large amount of a peptonising ferment exists, a fact which, in conjunction with investigation in the same direction by Claude Bernard and others, goes far to the elucidation of that complex phænomena. But upon this interesting subject time does not permit me to enter.

Amylolytic, emulsionising, and albuminosic ferments exist, then, in plants as well as in animals. They are essential for digestion in both kingdoms. Without them the proximate principles of food lie unavailable for the purposes of life. After digestion, the nutritive matters are distributed by transfusing the walls of the plant cells—for there is no closed vascular system—to the growing points, or, it may be, to the reservoirs of reserve material for subsequent use, whilst the

non-nutrient particles, after passing through various chemical changes, take the form of various excretions of the plant body.

What then of *Respiration* in plants? The combustion which accompanies the growth and development of plants, and the consequent production of heat, involves an evolution of carbonic acid; a supply of oxygen is therefore necessary, as in the case of animals, and it is only when the amount of this is sufficient that vital phænomena normally manifest themselves. Respiration is a process in plants—oxygen is inspired, carbonic acid is expired—so that the main gases in the interchange are the same in the two kingdoms of organic nature.

The phænomena of respiration are exhibited at all times and by all plants, both green and those not green. In the green plant, however, assimilation conceals during the day the respiratory process; but when with darkness assimilation ceases, the respiratory process fully discloses itself. To this fact may be ascribed the common misconception of the true significance of these functions and the unfortunate confounding of assimilation and respiration—and this, too, though so early as the fourth year of this century, Ingenhouss pointed out the relation between the processes. Indeed, the history of our knowledge of this subject furnishes a record of conflicting theories, based upon imperfect and faulty experiment, the outcome of which has been a general acceptation of the erroneous view that respiration in plants is of two kinds—a respiration in which oxygen is given off, which is termed a *day-respiration*, and a respiration of which the evolved product is carbonic acid, termed a *night-respiration*.

The masterly summing-up of the true facts of the case by Sachs a score of years ago, led on the Continent to the establishment of clearer notions upon the matter; but in this country the incorrect ideas of our forefathers are, I regret to say, still too widely prevalent, and I therefore the more earnestly reiterate the statement that respiration in plants is a process of combustion, the main factors of which are

the same as in animals—oxygen is inspired, carbonic acid is expired; and this process goes on at all times, so long as the plant retains vitality.

Plants, however, differ from animals in their power of living for a considerable time, even for days, when deprived of free oxygen; but in such an atmosphere they are unable to grow or to develope, and after prolonged exposure they die. How far for the simplest forms of vegetable life, the Schizomycetes (bacteria) and Saccharomycetes (yeast) this holds good, it is just now difficult to say in presence of the conflicting statements of able and accurate observers. For, whilst on the one side many researches, and amongst them the most recent, those of Nägeli, tend to show that under favourable conditions of heat, moisture, and a suitable nourishing medium, those forms are enabled both to maintain life and to propagate themselves in the absence of oxygen; on the other side it is maintained, and this is supported by elaborate and careful experiments, that oxygen is requisite for their propagation and growth.

Betwixt green and non-green plants there possibly exists a difference, previously unsuspected, in respect of respiration. Whilst the studies of Pringsheim, to which I have already referred, show that chlorophyll has no direct influence in assimilation, they have resulted in the discovery of what he regards as the true and only property of the chlorophyll,—to act as a screen interposed to protect the protoplasm of the cells from the too strong action of light; and as the inspiration of oxygen increases with the intensity of the light, the chlorophyll will thereby diminish the intensity of the respiration. It thus acts as a regulator of the respiration, and therefore indirectly promotes assimilation. In non-green plants there apparently resides no such factor.

In the respiratory process the direct interchange between the gases of the plant and those of its medium—the *external respiration*, as it is termed—in which the oxygen inspired is proportionate to the amount of carbonic acid expired, has been distinguished from that *intra-molecular*, or *internal*

respiration, the process going on in every cell where metastatic changes are in progress, which consists in a constant evolution of carbonic acid, and is manifested continually, even when the plant is in an atmosphere containing no free oxygen, though under such conditions with gradually decreasing intensity, until it ceases with the death of the cells. The relation betwixt the external and the intra-molecular respiration was for long a disputed problem. But these terms are merely expressive of two parts of the same process. As a result of the metastatic changes, intra-molecular respiration, marked by the evolution of carbonic acid, takes place, and the oxygen inspired by external respiration is requisite for the combustion of the products of the metastasis. In other words, whatever may be the actual chemical process and the intermediate products, there can be no doubt that metastasis is the cause of the intra molecular respiration, and that the external respiration is thereby induced. Now, as intra-molecular respiration goes on in all digesting cells, the oxygen must pass to them wherever situated. There is no closed vascular system nor medium of transit like the blood, and the mode of passage from cell to cell has been looked upon as a general diffusion of the gases; but a rather curious discovery has been recently announced by Jamieson of a substance in plant cells which, like the hæmoglobin of the blood, has a great affinity for oxygen, and acts as an oxygen-carrier to the ultimate tissues—a discovery which, if it be confirmed, may lead through further investigation to the establishment of other points of striking analogy in the two kingdoms.

These are the features in the digestion and the respiration of plants to which I ask your attention, and you will have perceived that digestion or metastasis in plants is a fermentation effected by ferments fitted for the several food principles; and concurrent with this, respiration supplies the oxygen requisite for combustion, and the evolved carbonic acid is removed.

I have here endeavoured to lay before you a parallel outline sketch of the processes of digestion and respiration in the

animal and vegetable kingdom, and the likeness is too striking to be mistaken. Starting from the one substance, protoplasm, the physical basis of all life, wherein is no difference we can recognise, but which is, nevertheless, endowed with a varying potentiality, in one instance exemplified in the development of an animal form, in another of a plant form, I have tried to show by one line of evidence how the fundamental unity in structure carries with it a unity in function, and that there is no duality of power in the two great kingdoms of organic nature.

It seems to me of some importance to bring out prominently at the present time this connection between the Natural History Sciences, and to point out their true relation, one to the other, in view of the wide-spread tendency in many quarters to underrate their value in medical education. Time was when the duties of a practitioner embraced not merely the diagnosis of and treatment of disease, but he was called upon to dispense the drugs he prescribed, and had to act as his own pharmacist. Then, undoubtedly, was it necessary that he should possess considerable knowledge of the systematic side of Botany, and have a thorough acquaintance with the specific characters and the sources of his medicines. But the time is past for Botany to be treated as a mere handmaid to Materia Medica. Modern Physiology has laid a foundation for the rational administration of drugs, and it is their therapeutic action which now more specially engrosses the attention of the profession; and in consonance with this aspect of medical science, it is the physiological side of Botany, and the morphological, in so far as required for a proper conception of the functional, of which a knowledge is valuable to the medical student. Plants are no longer to be regarded by him as merely objects, designated by long names, from which materials for making up prescriptions are derived; but as a student of life, he must see in them members of the living world endowed with faculties which make them powerful factors in the world's economy. Botany is to be studied as a Biological Science.

As you are all aware, there is at the present time an agitation for medical reform, heralded by the plausible cry of protection for the public. No one will deny that there is room for reform in certain directions, but it is open to grave question whether the sweeping changes in the character of the tests for medical licence and the modifications of the course of study which have been urged would produce the effect desired. It is hard to conceive of how lowering the standard of examination to a minimum would tend to the better protection of the public, or how the exclusion from the curriculum of study of those sciences, which even the reformers designate the fundamental medical sciences, would produce practitioners more fitted for the work of their profession.

It is often argued that such a procedure would relieve the now too-hard-pressed medical student, give him more time to devote himself to practical work, and save him from "wasting" a year of study. But surely if the medical student found the course of study which includes these fundamental sciences too great a tax for his powers, he would seek entrance to his profession through some portal—of which there are several—where the demands are not so severe. Is not the present status of the Scottish Universities a refutation of this? Again, would the introduction of a student to the practical work of his profession without that mental training which natural science offers enable him to acquire more rapidly a knowledge of his professional work? Would not his mind be less able to grapple with the problems which are suggested to it? Would not the gain of a year be merely nominal? No one, I take it, will advocate the advantage to a student of adopting some special line of medical study before he had acquired a knowledge of the general principles of disease. It might be said that thereby having more time to devote to his limited subject, he would acquire greater experience in it. But if such a course would not be expedient, wherein lies the benefit to the student of pursuing that special study which concerns the exhibition of life by man, before he has

learned something of life as seen in its simpler and more general developments?

The Scottish Universities, at least those of them that have raised their voice in opposition to the proposed lines of medical reform, so far as it touches the question of examinations and the course of study, are accused of being more concerned with their own interest and the preservation of their emoluments and of their monopoly, as it is termed, than with the interests of medical education. But I fail to recognise the grounds of this argument. The present agitation has no such basis as that which culminated in legislation at a former period—the protection of the public from quackery, and the destruction of the privileges enjoyed by certain corporations. The effect of the action of Parliament at that time has been to establish free trade in medical education. How can a monopoly be maintained now by any one body, when all come under the same regulations? This so-called monopoly of the Scottish Universities is, I venture to say, but an expression of the success which has attended the thorough training given by their system, and when accusations of such a character are brought forward, one cannot but suspect that underneath this cry for protection for the public there lies that of protection from the success of the Scottish Universities. I myself do not believe that any equitable plan of reform would appreciably affect the present position of the Scottish medical schools, so long as they continue to offer to the student the advantages of sound training and the opportunities for practical work which have contributed so largely to their success. The Scottish Universities assume a higher position than that of merely having care for self-interest; and found their opposition to the proposed alterations upon the prejudicial effect which they believe they must have on the social status of the medical profession in the future of the nation.

The value of the Natural History Sciences and their position in medical education is no new subject of contention, and I should not at this time have introduced so trite a matter, for I

cannot profess to advance any new arguments, but for the recent utterances in a weekly medical journal of one, from whom, as a graduate of a sister University, and for a time an assistant upon the teaching staff of this University, a want of appreciation in this respect was hardly to be expected. Giving reasons for the opposition by the Liverpool School to the proposal to include the power of granting a medical degree in the charter of the new Victoria University, he makes "some observations to show that the University of London ought to supply the desired degree," and in the course of these he passes a condemnation upon the system of study and examination enforced by that body. I have no intention of expressing here any opinion upon the character of these tests, and had the writer contented himself with a criticism of that system, his remarks would have passed as the opinion of a teacher in a great provincial school. But leaving the particular case of the University of London, the writer attacks in somewhat strong terms the principle of the introduction of the primary sciences into the medical curriculum, and appealing to his personal experience of, and connection with the Scottish Universities, poses as an illustration of the small amount of benefit which these sciences afford to a practitioner. But he shall speak for himself. He says:

"The examiners seem to think that the medical practitioner ought to be a peripatetic encyclopædia of Botany, Organic Chemistry, Mathematics, Natural Philosophy, Zoology, and Metaphysics—an excellent preparation, no doubt, for enabling the future doctor to treat the measles, manage a forceps case, or amputate a leg. I remember being pretty well dosed with these subjects myself. What Edinburgh man can ever forget the terrors of the Botany examination? All I can now say of the matter is, that my teachers did me a great injustice in wilfully compelling me to throw away a vast amount of valuable time and brain power in painfully burdening my memory with a collection of facts, not one of which has ever enabled me to do a patient a halfpenny worth of good, so far as I can remember. Ah! we are told, but look what a splen-

did mental training this is! Very likely. We used to be told that when we were boys, and had to excogitate from our wearied pates stumbling Latin Hexameters and cranky Greek Iambics, while we could not point out Dresden on the map, and knew as much about the French Revolution as we did about the Justinian Pandects. Mental gymnastics, forsooth! When a man is nineteen or twenty years of age, it is time he dropped these, and began to learn something useful."

It needs no great attention to recognise how valueless is all this intensity of expression, for it is nothing more, in support of the doctrine the writer wishes to advance, and as an argument against the present position of the Natural History Sciences (for it is with them only I am dealing), in medical education. Instead of an indictment against these, I venture to think the writer has framed one against himself. Few will be, from what he says, convinced of the injustice of his examiners. One is rather tempted to ascribe injustice, were there any, to his own act. For the reference to memory "painfully burdened" with facts, and to the "terrors" of examination, lead one to strongly suspect that his mind, never having subjected itself to that discipline of the scientific method which so greatly increases its power and efficiency, was unable, or at least unwilling, to assimilate the matters with which it had to deal, and that his "mental gymnastics" were confined to the acquirement of the "trick" or "craft of examinations," as it has been termed, obtained by the system of "cram"—a system to which the terrors of not only the Botany examination in Edinburgh, but of all examinations, are due. And in place of demonstrating the worthlessness of the Natural History Sciences in medical education, he rather furnishes a warning against "cram."

May one not consider that the writer in his letter does himself an injustice, by estimating so cheaply the amount of good which has accrued to him from his early college career; for it is difficult to believe that the mind at that time, so plastic and susceptible, should be uninfluenced by contact with scientific facts; and surely it is not reasonable to deny

effect to a cause, merely because one cannot register its amount?

It is indeed to be regretted that the writer was compelled "to throw away a vast amount of brain power," which might have served him now, and prevented his falling into the error of confounding the literary with the scientific method. This was not to be anticipated from one who, as he tells us, speaks with the authority of a fourteen years' experience in teaching the ingenuous youth of this country. But his comparison of the mental training from classical studies at school with the discipline which the Natural History Sciences supply is proof of his failing to recognise wherein lies the real value of these sciences in education. It is, I think, hardly necessary to point out to an audience such as this the different influence as a training which the learning derived from books, and the knowledge acquired by a study of things, as immediately made known by nature, have on the mind.

One certainly expects to find in one who assumes the function of criticising and of reforming a system of education, a thorough knowledge of the part which each subject in the system occupies or is capable of occupying, not only of itself, but also in relation to the whole. But when, as in the present instance, a critic displays so gross a misconception of the true faculty, which the Natural History Sciences perform in medical education, it is, I consider, one's duty to show at what rate to estimate his opinions.

The grounds of the value of the Natural History Sciences in medical education are twofold. In the first place, and most important, they supply a mental training which can be attained by no other means. The mind is brought directly into contact with fact. The student does not merely read about a thing, but learns to see for himself what it really is; and the fact becoming in this manner known to him, his intellect is exercised in drawing inferences from the fact, and thus becomes practised in the simplest form of induction. If then the Natural History Sciences are to be of use in disciplining the mind, it is evident that their teaching must be

thoroughly practical. Take up alone the theoretical side, and their power in imparting method is reduced.

In the second place, as holding the position of the fundamental sciences of life, the Natural History Sciences are of value to the medical student. The student studies life's manifestations in their most simple expressions, and thereby obtains an insight into the manner of Nature's working, which affords him a valuable clue to the explanation of many of those complicated phænomena exhibited in its highest development—Man.

And there is yet another point of view from which the Natural History Sciences may be regarded as beneficial in education. The beauty of the objects with which they deal is well calculated to give us pleasure and delight, which we cannot afford to neglect, and should endeavour to cultivate. Do not mistake me to say that a knowledge of these sciences will of itself augment our appreciation of this beauty. But it is of value in furnishing us with a catalogue of the pictures in Nature's gallery, in leading us to search for the beautiful in nature, and thereby opening up to us an unlimited field of enjoyment and recreation.

In commencing my remarks I disavowed the intention of offering to you counsel or advice, but, ere I close, allow me, addressing myself to those who are now entering upon their medical studies, to impress upon them the importance of a close attention at the outset of their career to the Natural History Sciences, which, neglected now, can never in future life be properly learned. Some there are who press the student at once into hospital work, holding that he cannot too early familiarise himself with the aspects of disease; and the neglect of the fundamental sciences which such a procedure involves, is, they think, amply compensated by the experience acquired. But, gentlemen, honest work, upon the foundations of science, alone will furnish a basis upon which to build the superstructure of the knowledge requisite for the proper practice of your profession. Those who hurry into hospital work may

for a time appear to succeed, they may seem to make rapid progress, and to have outstripped all who have devoted the early portion of their course to scientific work; but be not deceived, the advantage is not real, the success is but transient, for wanting the broad basis of a general knowledge of life, they are unable in the future to appreciate the wide issues which the healing art involves; they are apt to practise their profession as a mere routine of empiricism; they fail to grasp the idea that it is a science as well as an art.

I have done; and, in conclusion, I congratulate you on the commencement of another session. A season of hard mental work lies before you. Set to it diligently, earnestly; at the same time do not forget that besides the mind, the body must be exercised, and do not allow a desire for success in your studies to interfere with a due and proper amount of recreation. Remember that to work too much is as hurtful as to work too little, that the best work is accomplished when the sound mind is associated with a sound body. And in all things, in every field in which your energy may be exerted, strive to fulfil the precept, "Whatsoever thy hand findeth to do, do it with thy might."